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Particle Swarm Optimization based Load Frequency Control in Two Area Power System

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ABSTRACT: In this paper, determining the optimal proportional- integral-derivative (PID) controller gains for Two-area load frequency control (LFC) system using particle swarm optimization (PSO) is presented. The LFC is notoriously difficult to control optimally using conventionally tuning a PID controller because the system parameters are constantly changing. It is for this reason the PSO as tuning strategy was applied. The PID control parameters are tuned based on PSO algorithm. Hence the results establishes that tuning the PID controller using the PSO technique gives less over shoot, system is less sluggish and reduces the integral time absolute error (ITAE). The simulated result are obtained for different load configurations of the PSO based controller. The simulation has been conducted in MATLAB Simulink package for two area power system

Keywords: Load Frequency control, Two area power system, Particle swarm optimization, PID Controller.

I. INTRODUCTION

In electric power generation, system disturbances caused by load fluctuations result in changes to the desired frequency value. Load Frequency Control (LFC) is a very important issue in power system operation and control for supplying sufficient and both good quality and reliable power. Power networks consist of a number of utilities interconnected together and power is exchanged between the utilities over the tie-lines by which they are connected. The net power flow on tie-lines is scheduled on a priori contract basis. It is therefore important to have some degree of control over the net power flow on the tie-lines. Load Frequency Control (LFC) allows individual utilities to interchange power to aid in overall security while allowing the power to be generated most economically. Generally, ordinary LFC systems are designed with Proportional-Integral (PI) controllers. However, since the "I" control parameters are usually tuned, it is incapable of obtaining good dynamic performance for various load and system change scenarios. Many studies have been carried out in the past about the load frequency control. In literature, some control strategies have been suggested based on the conventional linear control theory [1]. These controllers may be unsuitable in some operating conditions due to the complexity of the power systems such as nonlinear load characteristics and variable operating points. According to some authors, variable structure control [2] maintains stability of system frequency. According to [3], conventional PID control schemes will not reach a high of control performances.

Since the dynamic behavior even for a reduced mathematical model of a power system is usually nonlinear, time-variant and governed by strong cross-couplings of the input variables, special care has to be taken for the design of the controllers. For this reason, recently, a lot of artificial intelligence based robust controllers such as genetic algorithm, tabu search algorithm, fuzzy logic and neural networks are used for PID controller parameters tuning in LFC by authors [4, 5, 6, 7]. Since, Particle Swarm Optimization algorithm is an optimization method that finds the best parameters for controller in the uncertainty area of controller parameters and obtained controller is an optimal controller, it has been used in almost all sectors of industry and science. One of those areas is the load frequency control as shown in [8].

PSO is inspired by the ability of flock of birds or herd of animals to adapt to their environment. It was developed in 1995 by James Kennedy and Russ Eberhart while attempting to simulate the choreographed, graceful motion of the swarm of birds as a part of socio-cognitive study investigating the motion of collective intelligence in biological population. In PSO, a set of randomly generated solutions propagates in the designed space towards the optimal solution over a number of iteration based on large amount of information about the designed space [9].

The main objective of this study is to investigate the load frequency control and inter area tie-power control problem for two-area power system taking into consideration the uncertainties in the parameters of system. An optimal control scheme based particle swarm optimization (PSO) Algorithm method is used for determine the parameters of a PID controller.

The proposed controller is simulated for a two-area power system. To show effectiveness of proposed method several changes in demand of first area, demand of second area and demand of two areas simultaneously are applied. Simulation results indicate that PSO controllers guarantee the good performance under various load conditions.

II. OVERVIEW OF PARTICLE SWARM OPTIMIZATION

The PSO method is a member of wide category of Swarm Intelligence methods for solving the optimization problems. It is a population based search algorithm where each individual is referred to as particle and represents a candidate solution. Each particle in PSO flies through the search space with an adaptable velocity that is dynamically modified according to its own flying experience and also the flying experience of the other particles. In PSO each particles strive to improve themselves by imitating traits from their successful peers. Further, each particle has a memory and hence it is capable of remembering the best position in the search space ever visited by it. The position corresponding to the best fitness is known as pbest and the overall best out of all the particles in the population is called gbest [10-11]. PSO is basically developed through simulation of bird flocking in two-dimension space. The position of each agent is represented by XY axis position and also the velocity is expressed by Vx (the velocity of X axis) and Vy (the velocity of Y axis). Modification of the agent position is realized by the position and velocity information. Bird flocking optimizes a certain objective function. Each agent knows its best value so far (pbest) and its XY position. This information is analogy of personal experiences of each agent. Moreover, each agent knows the best value so far in the group (gbest) among pbest. This information is analogy of knowledge of how the other agents around them have performed. Namely, each agent tries to modify its position using the following information:

The current positions (x, y),

The current velocities (vx, vy),

The distance between the current position and pbest

The distance between the current position and gbest

This modification can be represented by the concept of velocity. Velocity of each agent can be modified by the following

$$V_i^{k+1} = \omega V_i^k + c_1 r_1 \times (P_{best_i^k} - X_i^k) + c_2 r_2 \times (G_{best_i^k} - X_i^k)$$

(2)

Where,

V_i^k = velocity of individual i at iteration k.

ω = inertia weight parameter

c_1, c_2 = acceleration coefficients.

r_1, r_2 = random no between 0 and 1

X_i^k = position of individual i at iteration k,

$P_{best_i^k}$ = best position of individual i until iteration k.

$G_{best_i^k}$ = best positionof the group until iteration k.

The following weighting function is usually utilized .

$$\omega = \frac{\omega_{max} - (\omega_{max} - \omega_{min}) \times iter}{iter_{max}} \quad \ldots(3)$$

Where

$\omega_{max}, \omega_{min}$ = initial and final weight

$iter_{max}$ = maximum iteration number,

iter = current iteration number

Each individual moves from the current position to the next one by the modified velocity in (2) using the following equation.

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad \ldots(4)$$

Where

X^k = Current searching point

X^{k+1} = modified searching point

V^k = current velocity

Fig 1 shows the concept of searching mechanism of PSO using the modified velocity and position of individual i based on (2) and (4) if the values of $\omega, c_1, c_2, r_1, r_2$ are 1.

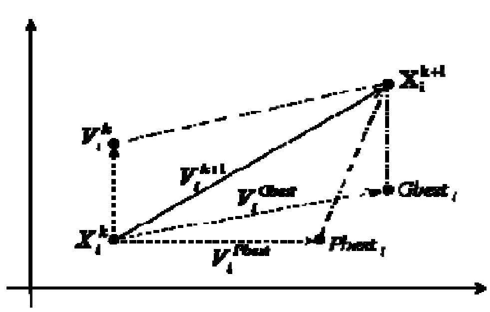

Fig. 1.

III. MODEL OF TWO AREA POWER SYSTEM

The two area interconnected power system is shown in fig.2, where Δf_1 and Δf_2 are the frequency deviations in area 1 and area 2 respectively in Hz. ΔP_{d1} and ΔP_{d2} are the load demand increments. A two area system consists of two single area systems, connected through a power line called tie-line, is shown in the Figure: 2 each area feeds its user pool, and the tie line allows electric power to flow between the areas. Information about the local area is found in the tie line power fluctuations. Therefore, the tie-line power is sensed, and the resulting tie-line power signal is fed back into both areas. It is conveniently assumed that each control area can be represented by and equivalent turbine, generator and governor system. Symbol used with suffix 1 refer to area 1 and those with suffix 2 refer to area 2.

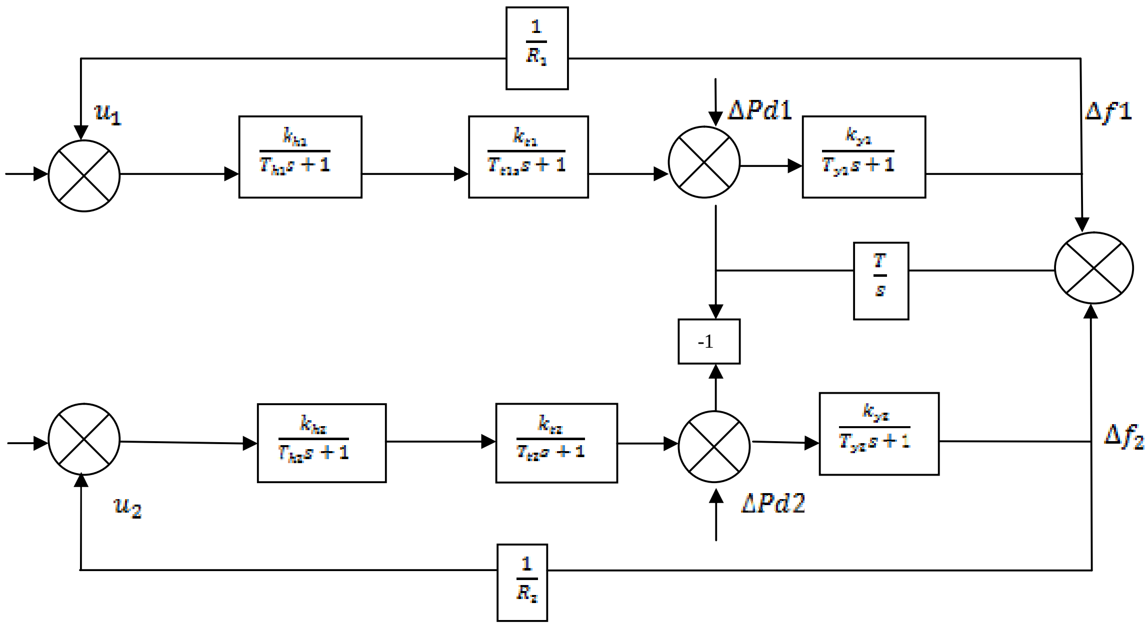

Fig. 2. Block diagram of Two area power system.

VI. MODEL WITH PROPOSED PSO-PID CONTROLLER

The framework of PSO based self-tuning PID controller is depicted as Figure 3. To find the optimum parameters (Kp, Ki, Kd) of PID controller, PSO program should search in 3-dimensional search space. In an ordinary load frequency control systems, Since a regulation constant R is used as Kp parameter in PID controller, especially I (integral) controller is used in LFC systems.

At the proposed system, R is also determine by PSO. So the regulation best value is used in LFC system. Thus ,for robustness, regulation constant is tuned according to load and system changes too. With the optimized parameter based on PSO algorithm, the proposed PID controller of the LFC can achieve optimal properties. The block diagram of a two area power system with this controller is shown in Fig 3.

V. SIMULATION RESULTS The Two area power system parameter are shown in table 1 and the value of regulation constant is also optimized by PSO. Simulation result for Two area power system are shown in table 2. During the simulation study, error signals $\Delta f_1, \Delta f_2$ and tie line power which is required for the controller is transferred to PSO software. All positions of particles on each dimension are clamped in limits which are specified by the user, and the velocities are clamped to the range [vmin., vmax.] given as [12]: a step load increase in demand of 0.01 p.u is applied to area 1.

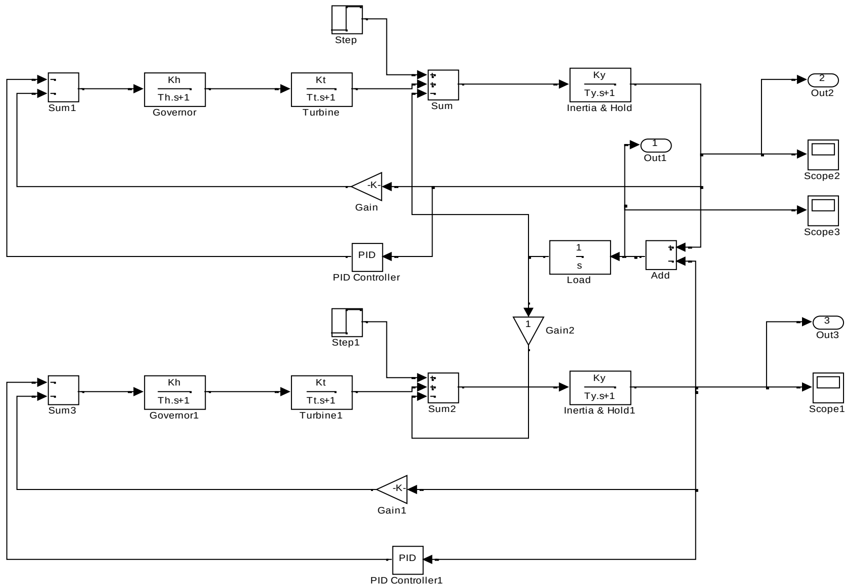

Fig. 3. Block diagram of two area power system with proposed PSO controller.

The frequency deviation of the first area Δf1 and the frequency deviation of the second area Δf2 and inter area tie-power signals of the closed-loop system are shown in Fig. 4, 5 and 6. Similarly a step load increase in demand of 0.01 is applied to area 2. Frequency deviation of the first area Δf1 and the frequency deviation of the second area Δf2 and inter area tie-power signals of the closed-loop system are shown in Fig. 7, 8 and 9.

At the simulation, the population size is taken 5.As can be observed, the settling time, overshoots, undershoot , settling value and rise time with the proposed PSO-PID controller are much better than other controller. Therefore, the proposed PSO-PID controller provides better performance for the two area power system In this simulation, the objective is to minimize the error and the maximum overshoot. For this reason the objective function is chosen as the Integral Time Absolute Error (ITAE).

Table 1.

Description	Area 1	Area 2
Governor Gain	1	1
GovernorTime Constant	80e-03	80e-03
Turbine Gain	1	1
Turbine Tine Constant	0.3	0.3
Load Model Gain	120	120
Load Time Constant	20	20
Ptiemax	200Mw	200Mw
Load change for Frequency change of	0.01	0.01

Table 2. System Performance for proposed PSO-PID controller for 1% load at area 1.

Parameter	Change in frequency in Area 1	Change in frequency in Area 2	Change in Tie line power
Overshoot	6.3545e-005	-6.1182e-006	6.9865e-006
Undershoot	8.5436e-007	-0.0024951	0.0024806
Settling Value	6.3545e-005	3.8562e-008	6.9867e-006
Settling Time	3.2932	2.1805	2.0179
Rise Time	0.00045816	6.9426e-006	7.0182e-006

Table 3. System Performance for proposed PSO-PID controller for 1% load at area 2.

Parameters	Change in frequency in Area 1	Change in frequency in Area 2	Change in Tie line power
Overshoot	4.8924e-006	0.00014426	0.00050426
Under Shoot	2.0729e-005	0.0000132	2.5578e-005
Settling Value	4.8932e-006	0.0011533	0.00050426
Settling Time	4.6426	2.2907	2.3822
Rise Time	3.4458e-005	0.56925	4.6313e-008

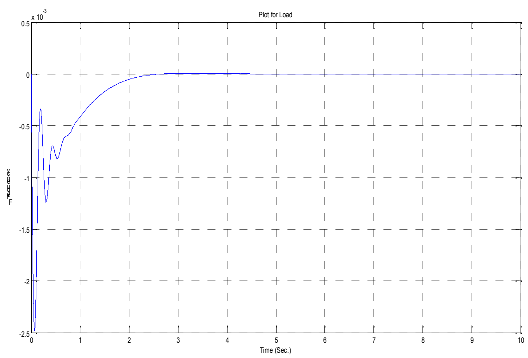

Fig. 4. Change in frequency in area 1 for a step load of 1% in area 1 with proposed PSO-PID controller.

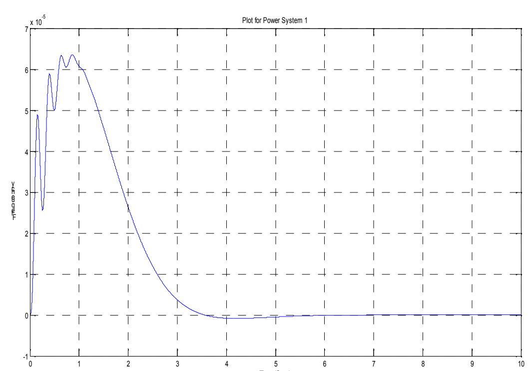

Fig. 5. Change in frequency in area 2 for a step load of 1%In area 2 with proposed PSO-PID controller.

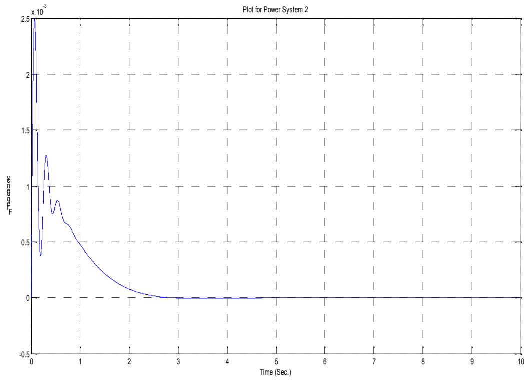

Fig. 6. Change in tie line power for a step load of 1% at area 1.

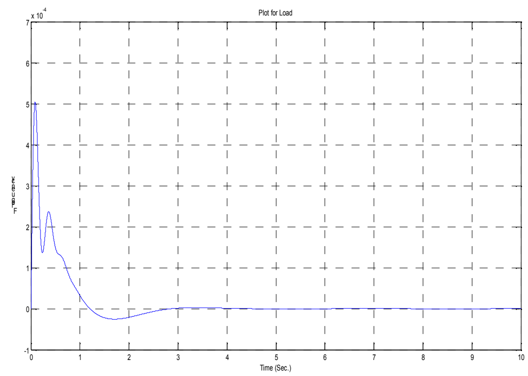

Fig. 7. Change in frequency in area 1 for a step load of 1% in area 2 with proposed PSO-PID controller.

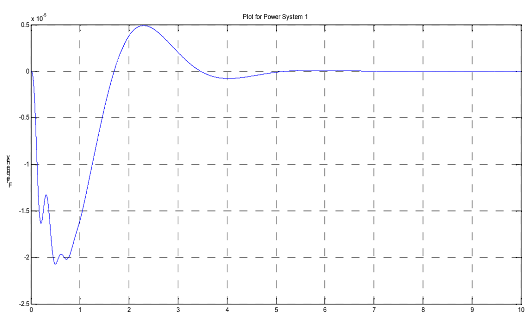

Fig. 8. Change in frequency in area 2 for a step load of 1% in area 2 with proposed PSO-PID controller.

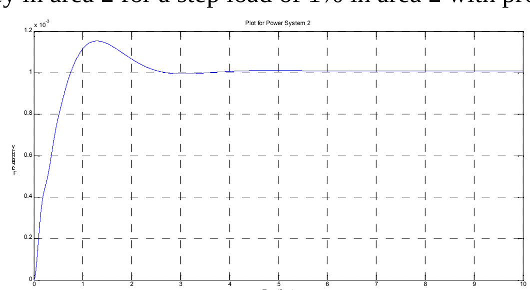

Fig. 9. Change in tie line power for a step load of 1% at area 2.

VI. CONCLUSIONS AND FUTURE WORK

In this study, a new particle swarm optimized LFC has been investigated for load frequency control of a Two area power systems. For this purpose, first, to obtain more adaptive tuning mechanism for the PID controller parameters and sensitivity of the system is increased. It has been shown that the proposed control algorithm is effective and provides significant improvement in system performance. Therefore, the proposed PSO-PID controller is recommended to generate good quality and reliable electric energy. In addition, the proposed controller is very simple and easy to implement since it does not require many information about system parameters. It is found very clearly that the PSO based controller drastically reduces the overshoot by a large value. Settling time, Rise Time and Peak Time have also improved. As a further study, the proposed method can be applied to multi area power system load frequency control and also optimum values can be obtained by Particle Swarm optimization and compare with Genetic Algorithm.

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